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Li Zishang and Mao Jingli

Reliability and maintainability are major standards for measuring the superiority of an aircraft. They are major factors in the combat capabilities of the Air Force. Striving to improve and enhance the reliability and maintainability of the aircraft with which the Naval Air Forces are currently primarily equipped, the Jian 6 and the Jian 7, are urgent tasks of Air Force maintenance operations. This article presents a thorough and wide ranging survey of aircraft manufacturing facilities and Naval Air Force Unit plants, and by combining, analyzing and studying this survey, it presents methods and means of improving the reliability and maintainability of the Jian 6 and Jian 7 aircraft.

In modern combat, air forces are in on the first assault. They primary assault forces in breaking through defenses and in destroying enemy military targets. Success or failure in a battle or campaign is often determined by the use of air force combat power as well as its mobility and coordination to bring about air superiority. Striving for maximum sortie strength and rapid response is also an important factor in how the combat progresses and in success or failure.]

The modernization of combat has greatly increased the "penetration, variability, speed and destruction" of warfare. At the same time, the widespread use of reconnaissance satellites and computers have greatly restricted "secrecy". Therefore, "speed is precious in war" is even more important. This requires that military air maintenance must react in the shortest possible time, ensuring the maximum sortie aircraft strength. Under these complex conditions, ensuring that aircraft possess the greatest possible tactical

capabilities and the repair of damaged aircraft under adverse conditions make even greater demands on the reliability and maintainability of aircraft. Therefore, to a certain extent, the improvement and enhancement of the reliability and maintainability of aircraft is equal to a positive improvement of the air forces combat capabilities.

The primary combat aircraft with which our force is currently equipped, the Jian 6 and Jian 7, were designed in the fifties. At that time very little consideration was given to reliability and maintainability. Therefore, the Jian 6 and Jian 7 aircraft require a great deal of maintenance work and require a frequent scheduled inspections and overhaul. This results in about 25 percent of all aircraft being in long term maintenance and not in use. Maintenance equipment is large and heavy, and there is a great deal of it, making it difficult to transfer aircraft from one airfield to another. Maintenance costs are very high, with lifetime maintenance costs for the Jian 6 being more than 2.5 times the purchase cost of the aircraft.

Reliability and maintainability operations began relatively late in China. These operations may be divided into two categories. (1), is making reliability and maintainability demands when research and development of a new aircraft begins. Because of the restrictions of certain conditions, some of these demands can only be partially met. (2), For older aircraft, only supplementary measures may be taken, adding these requirements during modification designs. The former requires that overall assembly plants and all the part manufacturers be given corresponding instructions, which covers a wide area and is very difficult. The later is only some checking around of the present basis of older aircraft, and because they have already entered the later period of their life expectancy,m it is not possible and is not necessary to perform any major surgery which is economically and practically not permissible. This restricts the directions we may take

in improving the reliability and maintainability of our aircraft currently in service. This is simplicity and economically over a small area with major results.

In order to do this, we analyzed the reliability of the Jian 6 and Jian 7 aircraft and make recommendations and propose measures for improving their reliability and maintainability.

I: AN ANALYSIS OF THE RELIABILITY AND MAINTAINABILITY OF THE JIAN 6

The Jian 6 aircraft is a 1959 Chinese copy of the Soviet MNT-19. The MNT-19 was the Soviet first supersonic fighter. It was designed in the late forties and was test flown and the model finalized in 1954. When this aircraft was designed, primary considerations were given to tactical capabilities, especially breaking the sound barrier. Very little consideration was given to reliability and maintainability. The poor reliability and maintainability of the Jian 6 aircraft overall can be summed up into six areas.

1. Low Part Reliability and High Failure Rate

This problem has remained unsolved for a long time. Examples of these are the Penkou II electromagnetic switch does not operate, residual air in the QS-02 brake distributer and leaks in the shaft of the hydraulic pump. These problems have still not been reduced. In 14 years, just these three malfunctions have caused 64 aborted flights. This is 5.6 percent of mechanical aborted flights.

According to the statistics of a certain unit, in recent years, 29.4 percent of the 34 LB-3 oil pumps malfunctioned in less than 100 hours of flying time following overhaul. Despite the fact that 26 of the bearings, or 38.3 percent, had been replaced during major overhaul, during the first 100 hour inspection following overhaul 19, or 27.9 percent, had to be thrown out, and the ball bearings in some had been

pulverized.~

The Jian 6 aircraft uses all flared guide connections, which are frequently disconnected, creating crystalline cracks, and the effects of high frequencies result in crack expansions or the connections falling apart. The plug connectors use a rubber washer seal which easily ages and deteriorates, becomes oil soaked, leaks air and malfunctions. There does not seem to be any way to prevent this.

2. Numerous Maintenance Points, Frequent Maintenance, and Large Amounts of Work

Maintenance Man Hours per Flight Hour (MMH/FH) is a primary indicator of maintainability. The MMH/FH of some domestic and foreign aircraft are shown in the following table:

AIRCRAFT:	F-4E	F-16	F111	J6	J8
MMH/FH	27	12	7.25	80.1	>100

The reason for such a large difference is that the Jian 6 aircraft has such a large number of checks and so many things listed for scheduled checks, that they have to be checked so many times. For example, at the 200 hour scheduled inspection, 76 parts at 53 points must be removed. At the 400 hour inspection, 121 parts must be removed at 88 points. Furthermore, when the aircraft can be used for a short time following overhaul of the aircraft of the engine, which requires a great deal of work. We will use the disassembly of the engine as an example to illustrate this point.

In advanced design, every effort is made to simplify disassembly and to shorten the time to replace engines. It makes wide use of oblique frame structure where the tail of the plane is not removed. It uses aircraft rail installation of the engine (the so-called tunneling method).

Furthermore, when replacing engines in the Jian 6, the tail of the aircraft must first be removed, the front and rear portions of the aircraft separated, entailing the removal of three guide pins, 24 screws, the 67 screws on the tail cowling as well as four hydraulic self sealing connectors, six hydraulic hoses leading to the jet action barrel, and dozens of safety conduits and cable slots. This requires a great deal of work and is very difficult. During installation, the conduit is easily bent making it difficult to line up. There can be oil leaks at the conduit flaring and the nut safety wires, which can lead to fires at high temperatures. It takes seven to eight men two hours to replace an engine. The engine replacement times of some domestic and foreign aircraft are provided in the following table:

AIRCRAFT	J7	J6	F-43	MIRAGE-2000	A-70	F-16
TIME	1350	240	37	37	25	20

3. Poor Accessibility and High Difficulty of Maintenance

Accessibility is a measurement of the difficulty in getting to the parts for inspection, testing, removal and installation, adjustment, cleaning, lubrication and repairs. Two standards for measuring accessibility are:

$$A_1 = \frac{\text{total area of aircraft maintenance ports}}{\text{total area of aircraft}} \times 100$$

$$A_2 = \frac{\text{total area of aircraft rapid removal maintenance ports}}{\text{total area of maintenance ports}} \times 100$$

AIRCRAFT:	J7	J6	F-4E	F-16
A_1	9.5%	21.7%	25%	60%
A_2	21%	26.1%	80%	35%

Poor accessibility makes maintenance operations extremely difficult. It results in maintenance which takes many times longer.

For example, when the Jian 6 supplementary hydraulic system reservoir is repaired in the field, because of the temperature of the work environment, the rubber bladder often cracks. When this happens, then the tail section must be taken off before it can be removed, requiring three hours of work for seven men. If field replacement of the reservoir had been considered during the design of the aircraft, and a larger port had been installed near the reservoir, then one man could replace the reservoir in only 15 minutes. Also, the first stage compressor blades of the engine have cracked and broken off, causing numerous serious accidents. However, there is no inspection port, and no suitable inspection method, so the only thing that can be done is to brave the cold or heat and crawl into the intake. This type of situation is very common on the Jian 6.

The poor accessibility of the Jian 6 aircraft is also demonstrated through the twisting and turning required to work on it. Most of the work ports are installed on top of or below the aircraft so that the repairmen frequently have to kneel, lie down, squat or bend over in order to work on the aircraft, affecting the efficiency of their work. It also can easily cause accidents. According to 1985 statistics at a certain repair plant, following repair to the front of the Jian 6 aircraft, reassembly requires 632 hours, during which the repair personnel are required to assume the following positions:

POSITION:	SQUATTING	KNEELING	BEND OVER	OTHER	TOTAL
HOURS:	293	111	33	195	632
PERCENTAGE:	46.4	17.6	5.2	30.8	100

4. Many Interconnected Operations, much Wasted Labor

The Jian 6 aircraft equipment layout is not very reasonable, and the various special parts are laid on top of one another, resulting in overlapping operations when working on the engine. Much labor is wasted labor. This is demonstrated through two situations.

First, when certain specialists are to work on the aircraft, other specialists have to remove or install some parts before they can do their work. For example, when mechanics are removing the brake pressure regulators, the starter case must be removed by specialists. When removing the 50 pressure reducer of the air conditioning system, armament specialists have to remove the right gun. Such overlapping operations exist in 80 different places on the Jian 6 aircraft.

The second is that equipment of several specialties is placed into a single work chamber. Because of space limitations, it is not possible for them to work at the same time. This is especially pronounced in the cockpit. According to statistics, when the Jian 6 is undergoing the 20 hour regular scheduled inspection, as many as 52 trips have to be made to the cockpit, but only one man can go into the cockpit at a time. Therefore, the time in the cockpit frequently affects the overall inspection time and the progress of the inspection.

5. Repair Equipment and Tools Are Out of Date and Inefficient

Our aviation service men are still using such simple tools as pliers, wrenches, hammers and screw drivers. Inspection methods are basically still done by the primitive methods of feel, sight, hearing and smelling. Therefore, damaged parts often make it through inspection resulting in major malfunctions. For example, refueling of the Jian 6 aircraft is still done byu looking and listening to determine when to shut off the nozzle. If it is just a little too late, then there is an "overflow", requiring removal of the tail portion to clean out the fuel and resulting in extra work and the aircraft missing a flight. Another example is the large number of bolt fasteners on the aircraft. The amount of force used to tighten them is something that a person has to learn through experience. They are often either too loose (and shaken off during flight causing an

accident) or too tight (twisting off the bolt or stripping the threads). On one occasion during a 50 hour inspection, after removing the booster main tube, the maintenance technician stripped three threads when turning the base bolt, which resulted in an oil leak and fire when the engine was started and the engine burned up.

The tools and equipment of the units with Jian 6 aircraft are mostly those issued when the aircraft were assigned. They have been used for more than 20 years, and are old and damaged and some are missing or can no longer be used. For example, at a certain unit they were removing the tail jet tube for a Jian 6 100 hour inspection when the tail jet tube was pinched because the tail support was unstable. The booster combustion chamber diffuser section was damaged beyond repair. According to statistics, many similar problems have occurred in the Naval Air Force.

Many measurement tools and calibration and inspection instruments have fallen into a state of disrepair and out of calibration from being used for so many years. According to 1985 statistics, of the 91 instruments of the electronics specialty of a certain Regiment, six could not be used and 85 were out of calibration. Of 122 instruments of the special equipment specialty, 13 could not be used and 92 were out of calibration. When instruments and equipment is not accurate, it will cause errors in repairs, and even dangerous consequences. For example, when a certain unit used a thermocouple to adjust the engine exhaust temperature, because of a large error in the thermocouple reading, it indicated that the temperature was lower that it actually was, it resulted in overheating and the engine burned up.

The outdated state of equipment is also indicated by the large amount of equipment used for regularly scheduled inspections, and the poor efficiency and capabilities of this equipment. According to statistics, one Jian 6 regiment has 60 to 90 tons of repair equipment which takes up 300 to 400 cubic meters of space. When other material

is added to this, it takes 15 to 20 railroad cars to transfer from one field to another, resulting in poor mobility.

6. Unreasonable Structural Design, Poor Maintenance Safety

The Jian 6 Aircraft was restricted by historical conditions at the time, and almost no consideration was given to maintenance safety. Therefore, during actual maintenance operations, it is impossible to avoid the two following situations.

1. Aircraft Part Installation Often Results in Human Error

There is no error prevention design in the Jian 6 aircraft. During repairs, installation errors, backwards connections, and misaligned parts can easily occur. This often leads to damaged parts, resulting in an aircraft having to abort its mission or not take off. It can even be a threat to safety. Air Force statistics for 1,081 flight accident symptoms show that 39.4 percent of them were caused by human error. According to a survey, the Jian 6 aircraft has 39 locations where human error can easily occur.

The Jian 6 aircraft has many conductors, conduits, receptacles and plugs of the same dimensions close to the same location, so it is very easy to make mistakes in connecting them. Many parts appear the same or similar on the outside, and if they are not clearly differentiated, it is easy to install the wrong part. For example, the Jian 6 operational jet does not have positioning equipment, and a unit once installed it 180 degrees backwards, and burned up the engine. The various dials in the cockpit all look alike, and the size of the installation holes are about the same. It is easy to install the wrong dial in a nearby position. In the past, the engine RPM indicator and exhaust temperature indicator have installed switching positions. This was not discovered until the aircraft was in flight. Similar occurrences are constantly occurring, and nothing seems to be able to

prevent them. The real reason is that there was no error prevention design.

2. Maintenance Errors Can Easily Result in Injuries and Damages

Because no consideration was given to protection measures during the design of the Jian 6, there have been numerous occurrences of the following during maintenance: seat ejection, firing of guns, engine catching fire, damage to engine by clamps during test running, raising the landing gear by mistake on the ground, dropping the auxiliary fuel tanks and bursting fuel tanks during pressurization. All of these have resulted in injuries to personnel and serious damage to state property.

The Jian 6 engine inspection ports all open at the top, and there are no ports at the bottom. Even if drop cloths are spread and tools are tied to ropes, nuts and washers still keep falling down, necessitating removal of the tail portion or even removal of the engine to find what has been dropped inside. In the process of removing and replacing the engine and tail portion, damage often occurs to parts because of the difficulty of the operation.~

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